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Yield and Quality of Beetroot (*Beta vulgaris* L.) Varieties in Inner Terai Area of Sindhuli, Nepal

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Abstract

A field experiment was conducted in the Horticulture Farm of the College of Natural Resource Management, Kapilakot, Sindhuli, Nepal, from November 2019 to January 2020 to evaluate the effect of growth, yield and quality of beetroot (*Beta vulgaris* L.) varieties. The experiment was laid out in a single-factor randomized complete block design with four replications consisting of nine beetroot varieties, i.e., Detriot Dark Red, Jhelum, Action, Ruby Red, Ruby Queen, Maharaja, Madhur, Red Express-505, and Bikores. Results of this study indicated a significant effect of varieties on the measured parameters. During harvest, a significantly higher plant height (43.4 cm), number of leaves per plant (14.47), leaf length (40.91 cm), and leaf width (12.42 cm) were observed in the variety 'Action', which was followed by 'Red Express 505' and 'Madhur'. Total root length (14.37 cm) was found longest in Red Express-505. However, edible root length (9.95 cm) and beetroot diameter (70.81 mm) were found to be higher in Action than in other tested varieties. Likewise, higher economic yield (36.76 t ha^{-1}) and biological yield (57.06 t ha^{-1}) were also recorded in the Action variety compared to other varieties. Root dry matter (9.95 %) and leaf dry matter (9.07%) were highest in Action. However, total soluble solids were found significantly higher in (10.97^0 Brix) in the Ruby Queen variety. Likewise, the colour, taste and overall acceptability were highest in the Ruby Red variety of beetroot. Therefore, based on the results of the experiment, variety Action was better for optimum yield and Ruby Queen and Ruby Red for quality beetroot production in the inner Terai area of Sindhuli, Nepal.

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Keywords

Beetroot; Varieties; Yield; Quality

Introduction

Beetroot (*Beta vulgaris* L.), a member of the Chenopodiaceae family, which is also called garden beet or table beet, is a biennial crop grown as an annual for its fleshy roots (Sri Vidhya and Radhai, 2018). Beetroot is one of the oldest vegetables known to mankind and is thought to have originated along the coast of the Mediterranean from wild sea beet (*Beta vulgaris* L. ssp. *maritime*) by hybridization with *B. patula* (Bose *et. al*., 2003). It is a crop of the temperate region which requires cool weather and high relative humidity. During the first growing season, it produces green tops and swollen tap roots and produces flowers and seeds in the second season. The swollen roots are eaten as salad, boiled, pickled or canned, and sometimes consumed as juice (Kanner, Harel and Granit, 2001). It is an important root crop grown in home gardens as well as on a commercial scale for its fleshy enlarged roots, and it has nutritional, medicinal, culinary and industrial significance (Patel, Sharma and Varma, 2015).

In recent years, beetroot has attracted much attention as a health-promoting functional food (Clifford *et al*., 2015). The popularity of this root vegetable is mainly associated with its renewable and cheap source of nutrients (Goldman and Navazio, 2008). Beetroot is a rich source of carbohydrates, fibers, proteins and minerals such as sodium, potassium, calcium and iron (Chiej, 1984). The rich fiber content in beetroot prevents constipation and lowers cholesterol levels**.** Purple-crimson color of beetroot is due to the pigment betacyanin, which helps to suppress the development of cancer and possesses antioxidant properties (Rey *et a*l., 2005). Its low-calorie density is suitable for calorie-controlled diets. It also contains several vitamins and a significant level of magnesium, selenium, folate, and phytosterols; hence it is an ideal vegetable for health-conscious people (Deuter and Grundy, 2004).

Other than food, it plays another role as a natural colorant in textile industries and as a medicinal plant to cure various illnesses. The functional bio-active compounds and natural coloring pigment present in beetroot have a new opportunity in dairy and food products (Deshmukh *et al*., 2018). It is one of the potential sources of water-soluble nitrogenous pigment, called betalins, which is responsible for the intense red color of beetroot and used in the modern food industry as an important natural colorant (Azeredo, 2009; Pedreno and Escribano, 2001). It is one of the natural foods which boosts energy in athletes as it has one of the highest nitrates and sugar content of plants (Jasmita, Shenoy and Hedge, 2018). The juice of the beetroot is used as a natural remedy for sexual weakness and to expel kidney and bladder stones. It is a potential herb used in cardiovascular issues and has anti-tumor, emmenagogue, hemostatic, and renal protective properties (Kale *et al*., 2018).

Beetroot is gaining a high level of economic importance both in terms of income generation and nutritional value. Besides nutritional importance, the cost of cultivation of beetroot is less due to dense foliage, which keeps most weeds at bay and is less attacked by pests and diseases. Despite the minimum cost of cultivation with higher market and nutritional value, the beetroot crop remains neglected in Nepal. There are many influencing factors in beetroot production. However, the important ones are the proper selection of the varieties. Selection of cultivar plays a crucial role in the production of superior quality roots, but the research work done on these aspects is very

meager in Nepal. The scientific vegetable production reveals the significance and importance of suitable varieties for raising vegetable crops in order to get higher production of good quality vegetables. In Nepal, different genotypes of diverse crops have been created and maintained because of the benefit from the diverse climate across the country (Upadhaya and Joshi, 2003). These are not added to the national variety list. Variety needs to pass through some laws and regulations to be added to the national list, i.e. released and registered genotypes (SQCC, 2014). The use of hybrid varieties is increasing year after year in Nepal (Rawal *et al*., 2017).

Beetroot is a relatively new crop, and major constraints in production are the selection of suitable varieties in different agro-ecological regions of Nepal. There is a research gap in the selection of the appropriate varieties in this underutilized crop. Therefore, the focus of this research is to identify and evaluate suitable varieties of beetroot with growth, yield, and quality in the inner Terai[1] area of the Sindhuli district of Nepal.

Materials and Methods

Study site

The experiment was conducted in field conditions at Agriculture and Forestry University, College of Natural Resource Management, Kapilakot, Sindhuli, located at $27^0$15' north latitude and $85^0$44' east longitude with an elevation of 290 masl. The research site was selected due to its suitable agro climatic conditions for the production of beetroot in Nepal.

Agro-climatic condition of the research site

The meteorological data of the experiment site during the cropping period was collected. The weekly average data on different weather parameters, i.e. maximum temperature, minimum temperature, relative humidity, and total rainfall during the growing season of beetroot, are presented in figure 1. The maximum temperature ranged from 22.6°C (4^{th} week of Dec 2019) to 29.65°C (1^{st} week of November 2019). The minimum temperature ranged from 7.9°C (1^{st} week of January 2020) to 16.7°C (1^{st} week of November 2019). Likewise, the average RH of the cropping period was 91.86 %. Total rainfall (11.5 mm) was recorded during the 4^{th} week of January 2020.

Soil properties

A composite soil sample was taken from the experimental field from 15 cm soil depth by using the screw auger before sowing of beetroot seeds. The composite soil sample was air dried, ground and sieved. Total N was determined by the Macro-Kjeldahl method, available phosphorus by the available P by Olsen's bicarbonate, and available K by the ammonium acetate method. Organic matter was determined by the Walkely and Black method, pH by Beckman Glass Electrode pH, and soil texture by hydrometer method at the Soil and Fertilizer Testing Laboratory of Bagmati Provincet, Hetauda, Makwanpur District, Nepal. The soil of the experimental field was acidic (pH 5.5), containing medium

[1] Terai is a lowland region in parts of southern Nepal and northern India that lies to the south of the outer foothills of the Himalayas.

organic matter (3.7%), medium available nitrogen percentage (0.13%), medium phosphorus (45.3 kg ha^{-1}) and high available potassium (135.3 kg ha^{-1}).

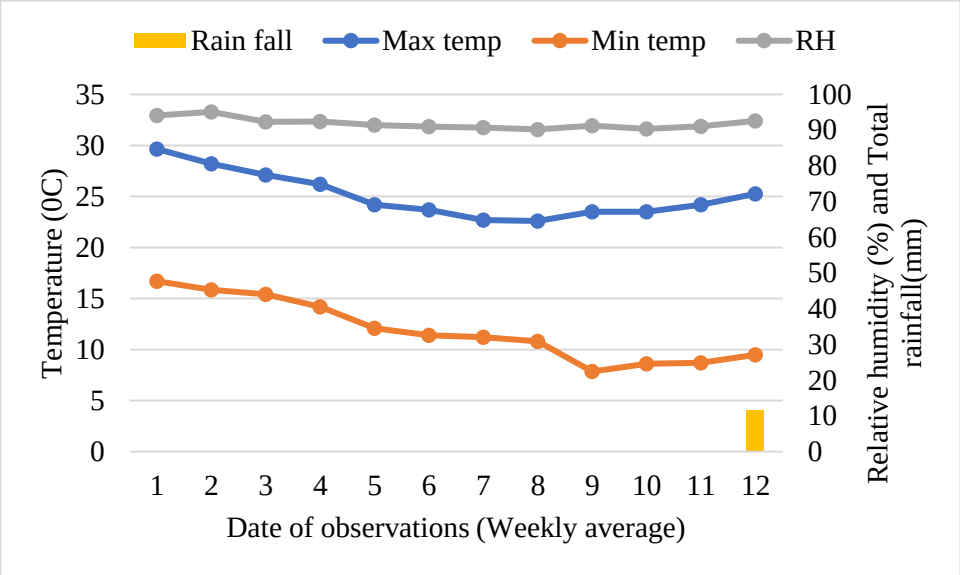

Figure 1: Average meteorological data of the experimental site from November 2019 to January 2020.

Experimentation details

A single-factor randomized complete block design (RCBD) was used in this research and replicated four times. The 9 varieties of beetroot, namely Detroit Dark Red, Jhelum, Ruby Red, Ruby Queen, Red Express-505, Maharaja, Bikores, Action, and Madhur, were collected from the public and private sectors from Kathmandu, Janakpur, and Birjung, Nepal. The details of the varieties used in the experiment are given in table 1.

Table 1: Varieties used in the experiment

Treatment number	*Variety*	*Source*	*Types*
T_1	Detroit Dark Red	Urja Seeds	Open pollinated
T_2	Jhelum	East West Seed	Hybrid
T_3	Action	Kalash Seeds	Hybrid
T_4	Ruby Red	Doctors Seed	Open pollinated
T_5	Ruby Queen	Pradhan Seeds	Open pollinated
T_6	Maharaja	Urja Seeds	Hybrid
T_7	Madhur	Namdhari Seeds	Open pollinated
T_8	Red Express-505	Gennext Seeds	Hybrid
T_9	Bikores	Kalash Seeds	Hybrid

Intercultural operations

All the organic and inorganic fertilizers were applied as per the recommended dose, i.e., 20 ton ha^{-1} FYM and 120:80:40 kg NPK ha^{-1} (AITC, 2018). There were a total of 36

plots, each of which was 1.8 m × 1.8 m in size. The seeds were sown on November 5, 2019, with a distance of 45 cm x 10 cm. All the intercultural operations, including thinning, weeding, and irrigation, were done regularly. Data such as plant height (cm), number of leaves per plant, leaf length (cm), breadth of longest leaf (cm), and canopy diameter (cm) were recorded after 30 days of seed sowing in every 10 days intervals. Root length (cm), edible root length (cm), root weight (gm), leaf weight (gm), economic yield (t ha^{-1}), and biological yield (t ha^{-1}), root dry matter (%), leaf dry matter (%), TSS (^{0}Brix), pH, and organoleptic test were recorded after harvest. An organoleptic test was done by a panel of 5 persons to judge the taste of beetroot after harvest by using a hedonic scale of 1 to 10, in which 1 indicated the poor and 10 the excellent in taste.

Data analysis

The collected data were compiled and subjected to analysis of variance using the Microsoft-Excel. R Studio version 4.2.3 was used for the analysis of variance of all parameters. Mean comparison was done at a 5% level of significance using Duncan's Multiple Range Test (DMRT). Microsoft-Excel was used for the construction of graphs and tables.

Result and Discussion

Plant height

Plant height differed significantly at 0<0.05 among the tested beetroot varieties at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS and at harvest (Table 2). At 30 DAS, the highest plant height, 13.53 cm, was recorded in the Action variety, which was statistically at par with Red Express-505, Madhur, Ruby Queen, and Ruby Red. The shortest plant height, 11.4 cm, was recorded in Bikores. At 40 DAS, the tallest plant height (24cm) was recorded in Red Express-505, while the shortest plant height (19.23 cm) was recorded in Bikores. At 50 DAS, significantly tallest plant was found in Red Express-505, which was statistically at par with Ruby Queen, Action, and Madhur variety. At 60 DAS, the tallest plant height (35.45 cm) was found in Ruby Queen, which was statistically at par with Red Express-505, Madhur, and Ruby Queen. At the final harvest, the variety Action had taller plant height (43.40 cm) while Bikores had recorded lower plant height (36.67 cm).

Table 2: Performance of varieties of beetroot on plant height at different days after sowing in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatment	*Plant height (cm)*					
	30 DAS	*40 DAS*	*50 DAS*	*60 DAS*	*70 DAS*	*At harvest*
Detroit Dark Red	11.73^{bc}	20.05^{cd}	26.52^{de}	30.61^{d}	34.67^{bc}	37.82^{de}
Jhelum	11.34^{c}	19.28^{d}	26.72^{cde}	30.65^{d}	34.26^{c}	37.95^{cde}
Action	13.53^{a}	22.51^{abc}	29.78^{abc}	34.1^{abc}	38.17^{a}	43.40^{a}
Ruby Queen	12.99^{ab}	23.43^{ab}	30.18^{ab}	35.45^{a}	38.77^{a}	40.68^{abcd}
Ruby Red	13.22^{ab}	20.91^{bcd}	27.18^{bcde}	31.46^{cd}	34.875^{bc}	38.86^{bcde}
Maharaja	11.80^{bc}	20.31^{cd}	27.23^{bcde}	31.62^{bcd}	34.88^{bc}	37.8^{de}
Madhur	13.40^{a}	22.28^{abc}	29.55^{abcd}	34.51^{ab}	37.6^{ab}	41.80^{ab}

Treatment	*Plant height (cm)*					
	30 DAS	*40 DAS*	*50 DAS*	*60 DAS*	*70 DAS*	*At harvest*
Red Express-505	13.45^{a}	24.06^{a}	30.48^{a}	34.64^{ab}	37.92^{ab}	41.63^{abc}
Bikores	11.4^{c}	19.23^{d}	26.18^{e}	30.15^{d}	33.83^{c}	36.67^{e}
SEM(±)	0.31	0.59	0.58	0.68	0.65	0.77
$LSD_{0.05}$	1.44**	2.46**	2.83*	2.8**	2.94**	3.4**
Grand mean	12.54	21.33	28.20	32.58	36.12	39.62
CV, %	7.91	7.92	6.88	5.89	5.58	5.89

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), SEM (±)-Standard error of mean, LSD - Least significant difference, and CV-Coefficient of variance, DAS- Days after sowing

Number of leaves per plant

The number of leaves per plant of beetroot varieties differed significantly at 0<0.05 at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS and at harvest (Table 3). At 30 DAS, the maximum number of leaves per plant (7) was recorded in the Madhur variety, which was statistically at par with Action and Red Express-505. At 40 DAS, the maximum number of leaves per plant (8.68) was recorded in Red Express-505, and the lowest number of leaves (7.12) was recorded in Jhelum. At 50 DAS, the highest number of leaves per plant (9.55) was produced by Action, which was statistically at par with Red Express-505 (9.48), Madhur (9.27) and Ruby Queen (9.2). Similarly, at 60 DAS, Action produced the maximum number of leaves (11.1), which was statistically at par with Madhur (10.41), Red Express-505 (10.41), and Ruby Red (10.37). At 70 DAS, Red Express-505 produced the maximum number of leaves (12.07), and Bikores produced the minimum number of leaves (8.42). At final harvest, Action produced the maximum number of leaves (14.47), which was statistically at par with Ruby Red (14.25), Red Express-505 (13.95), and Madhur (13.75). Jhelum produced the minimum number of leaves (11.32) at final harvest.

Table 3: Performance of varieties of beetroot on the number of leaves per plant at different days after sowing in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatment	*Number of leaves plant^{-1}*					
	30 DAS	*40 DAS*	*50DAS*	*60 DAS*	*70 DAS*	*Final harvest*
Detroit Dark Red	5.88^{c}	7.88^{abc}	8.12^{cde}	9.22^{cd}	10.42^{bc}	12.07^{c}
Jhelum	6.15^{bc}	7.125^{c}	7.88^{e}	9.21^{cd}	9.95^{c}	11.32^{c}
Action	6.82^{ab}	8.60^{a}	9.55^{a}	11.10^{a}	11.8^{a}	14.47^{a}
Ruby Queen	6.10^{bc}	7.61^{bc}	9.20^{abcd}	9.42^{bcd}	11.35^{ab}	12.52^{bc}
Ruby Red	6.15^{bc}	8.07^{ab}	8.27^{cde}	10.37^{ab}	11.40^{ab}	14.25^{a}
Maharaja	5.98^{c}	7.26^{bc}	8.35^{bcde}	9.812^{bc}	10.40^{bc}	12.45^{bc}
Madhur	7.00^{a}	8.10^{ab}	9.27^{abc}	10.41^{ab}	12.02^{a}	13.75^{ab}
Red Express-505	6.77^{ab}	8.68^{a}	9.48^{ab}	10.41^{ab}	12.07^{a}	13.95^{ab}
Bikores	5.80^{c}	7.40^{bc}	8.05^{de}	8.42^{d}	9.97^{c}	11.80^{c}
SEM(±)	0.14	0.18	0.22	0.27	0.28	0.38
$LSD_{0.05}$	0.66**	0.78**	1.05**	1.00**	1.22**	1.40***

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Treatment	*Number of leaves plant^{-1}*					
	30 DAS	*40 DAS*	*50DAS*	*60 DAS*	*70 DAS*	*Final harvest*
Grand mean	6.29	7.86	8.68	9.82	11.04	12.95
CV,%	7.22	6.8	8.29	6.99	7.58	7.41

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. **significant at 1% (p<0.01), *** significant at 0.1% (p<0.001), SEM (±)- Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance, DAS- Days after sowing

Leaf length

Leaf length of tested beetroot varieties differed significantly at 0<0.05 at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS and at final harvest (Table 4). At 30 DAS, the longest leaf length (10.64 cm) was recorded in Action, which was statistically at par with Red Express-505 (10.51 cm), Ruby Red (9.85 cm), Madhur (9.78 cm) and Ruby Queen (9.08 cm). At 40 DAS, maximum leaf length was produced by Ruby Red (21.96 cm) and the lowest leaf length was recorded in Bikores (17.31 cm). At 50 DAS, the longest leaf length was produced by the variety Action (33.14 cm), which was statistically at par with Red Express-505, Madhur, Ruby Queen, and Ruby Red. Similarly, at 60 DAS, Madhur produced the longest leaf length (34.91 cm) and Bikores produced the shortest (29.8 cm). At 70 DAS, Red Express-505 produced the maximum leaf length (39.47 cm), and Bikores produced the lowest leaf length (33.77 cm). At final harvest, Action produced the maximum leaf length (40.91 cm), which was statistically at par with Red Express-505 (40.40 cm), Madhur (39.47 cm), and Ruby Red (39.15 cm). Detroit Dark Red recorded the shortest leaf length (34.6 cm) at final harvest.

Table 4: Performance of varieties of beetroot on leaf length at different days after sowing in inner Terai condition of Sindhuli, Nepal, 2019/2020

Treatment	*Leaf length (cm)*					
	30 DAS	*40 DAS*	*50 DAS*	*60 DAS*	*70 DAS*	*At harvest*
Detroit Dark Red	8.48^{bc}	17.93^{de}	27.35^{bc}	30.96^{c}	34.01^{b}	34.^{60d}
Jhelum	7.71^{c}	18.54^{cde}	28.15^{bc}	31.58^{bc}	34.0^{b}	35.86^{cd}
Action	10.64^{a}	21.44^{ab}	33.14^{a}	34.29^{ab}	39.47^{a}	40.91^{a}
Ruby Queen	9.08^{abc}	20.405^{abc}	30.05^{ab}	31.29^{bc}	35.85^{ab}	36.91^{bcd}
Ruby Red	9.85^{ab}	21.96^{a}	29.70^{abc}	34.09^{ab}	36.63^{ab}	39.15^{abc}
Maharaja	8.60^{bc}	19.46^{bc}	27.945^{bc}	31.64bc	36.35^{ab}	37.16^{bcd}
Madhur	9.78^{ab}	18.11^{cde}	30.35^{ab}	34.91a	37.41^{ab}	39.47^{ab}
Red Express-505	10.51^{a}	20.05^{abcd}	32.39^{a}	34.64^{a}	38.41^{a}	40.40^{ab}
Bikores	7.77c	17.31e	26.38^{c}	29.80^{c}	33.77^{b}	34.83^{d}
SEM(±)	0.36	0.54	0.75	0.63	0.67	0.78
$LSD_{0.05}$	1.68**	2.16**	3.23**	2.73**	3.47*	3.21**
Grand mean	9.16	19.47	29.49	32.58	36.21	37.70
CV,%	12.59	7.61	7.51	5.74	6.57	5.83

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), SEM- Standard

error of mean, LSD - Least significant difference, and CV-Coefficient of variance, DAS-Days after sowing

Breadth of the longest leaf

Breadth of the longest leaf of beetroot varieties differed significantly at 0<0.05 at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS and at final harvest (Table 5). At 30 DAS, maximum leaf breadth was recorded in the Ruby Red (4.55 cm) variety, which was statistically at par with Red Express-505 (4.22 cm), and Action (4.12 cm). At 40 DAS, the highest leaf breadth was produced by Action (8.6 cm), and shorter leaf breadth was recorded in Detroit Dark Red (6.77 cm). At 50 DAS, the maximum leaf breadth was produced by Red Express- 505 (9.45 cm) and the lowest leaf breadth was recorded in Detroit Dark Red (7.35 cm). At 60 DAS, Red Express-505 produced the highest leaf breadth (10.75 cm) and Jhelum produced the lowest. At 70 DAS, Ruby Red produced the maximum leaf breadth (11.42 cm), and the Bikores produced the minimum breadth of leaf breadth (9.57 cm). At final harvest, Action recorded the maximum breadth of the longest leaves (12.42 cm), which was statistically at par with Red Express-505 (12.25 cm), Maharaja (11.47 cm), Ruby Red (11.47cm), and Jhelum recorded the minimum breadth of the longest leaf (10.25 cm).

Table 5: Performance of varieties of beetroot on leaf breadth of the longest leaf at different days after sowing in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatment	*Breadth of longest leaf (cm)*					
	30 DAS	*40 DAS*	*50 DAS*	*60 DAS*	*70 DAS*	*At harvest*
Detroit Dark Red	3.62^{bc}	6.77^{c}	7.35^{c}	8.72^{bc}	9.57^{b}	10.42^{b}
Jhelum	3.47^{c}	6.92^{c}	7.95^{bc}	8.15^{c}	9.85^{b}	10.25^{b}
Action	4.12^{abc}	8.60^{a}	9.10^{a}	10.27^{a}	10.95^{ab}	12.42^{a}
Ruby Queen	3.90^{bc}	7.47^{bc}	8.95^{ab}	9.47^{ab}	10.10^{ab}	10.65^{b}
Ruby Red	4.55^{a}	8.52^{a}	9.10^{a}	10.20^{a}	11.42^{a}	11.47^{ab}
Maharaja	3.75^{bc}	7.35^{bc}	8.80^{ab}	10.07^{a}	10.85^{ab}	11.47^{ab}
Madhur	3.77^{bc}	7.40^{bc}	7.95^{bc}	9.45^{ab}	9.80^{b}	10.7^{b}
Red Express-505	4.22^{ab}	8.12^{ab}	9.45^{a}	10.75a	10.92^{ab}	12.25^{a}
Bikores	3.55^{c}	6.87^{c}	7.67^{c}	8.60^{bc}	9.97^{b}	10.62^{b}
SEM(±)	0.11	0.23	0.25	0.29	0.21	0.26
$LSD_{0.05}$	0.57*	0.97**	1.03**	1.16**	1.21*	1.22**
Grand mean	3.88	7.56	8.48	9.52	10.38	11.13
CV,%	10.15	8.8	8.39	8.41	7.99	7.55

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), SEM (±)-Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance, DAS- Days after sowing.

Canopy diameter

Canopy diameter of beetroot varieties differed significantly at 0<0.05 at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS, and at final harvest (Table 6). At 30 DAS, maximum canopy diameter was recorded in Ruby Red (18.46 cm), which was statistically at par with Madhur (18.32 cm), and Red Express-505 (17.92 cm). At 40 DAS, maximum

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canopy diameter was found in Ruby Red (30.55 cm), which was statistically at par with Red Express-505 (29.7 cm) and Ruby Queen (28.55 cm). At 50 DAS, the maximum canopy diameter was recorded in Ruby Queen (32.53 cm), and the minimum was found in Jhelum. At 60 DAS, Ruby Red produced the longest canopy diameter of 35.9 cm and the shortest canopy diameter was recorded in Bikores (30.77 cm). At 70 DAS, Ruby Queen produced the maximum canopy diameter of 41.31 cm and the lowest was found in Jhelum (35.51 cm). Red Express-505 recorded the highest canopy diameter (43.9 cm), which was statistically at par with Ruby Queen (42.85 cm), Action (42.6 cm), Ruby Red (42.6 cm), Madhur (41.95 cm), and Jhelum recorded the minimum canopy diameter (38.36 cm) at final harvest.

Table 6. Performance of varieties of beetroot on plant canopy at different days after sowing in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatment	*Canopy diameter (cm)*					
	30 DAS	*40 DAS*	*50 DAS*	*60 DAS*	*70 DAS*	*At harvest*
Detroit Dark Red	15.40^{c}	25.91^{cd}	28.91^{b}	31.16^{d}	36.30^{cd}	38.85^{c}
Jhelum	15.30^{c}	25.61^{d}	28.78^{b}	32.10^{cd}	35.51^{d}	38.36^{c}
Action	16.27^{bc}	27.82^{bcd}	30.25^{ab}	32.52^{bcd}	38.77^{abc}	42.60^{ab}
Ruby Queen	16.25^{bc}	28.55^{abc}	32.63^{a}	34.93^{ab}	41.31^{a}	42.85^{a}
Ruby Red	18.46^{a}	30.55^{a}	32.46^{a}	35.90^{a}	40.67^{a}	42.60^{ab}
Maharaja	15.95^{bc}	26.65^{cd}	29.41^{ab}	32.86^{bcd}	36.07^{cd}	39.65^{bc}
Madhur	18.32^{a}	27.12^{bcd}	31.72^{ab}	34.47^{abc}	37.25^{bcd}	41.95^{ab}
Red Express-505	17.92^{ab}	29.70^{ab}	32.05^{ab}	35.78^{a}	39.75^{ab}	43.90^{a}
Bikores	15.50^{c}	25.52^{d}	29.1^{b}	30.77^{d}	36.67^{cd}	38.57^{c}
SEM(±)	0.42	0.60	0.53	0.64	0.71	0.71
$LSD_{0.05}$	1.85**	2.48**	2.94*	2.54**	2.81**	2.84**
Grand mean	16.59	27.49	30.59	33.39	38.03	41.02
CV,%	7.67	6.18	6.59	5.22	5.06	4.74

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), SEM (±)- Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance, DAS- Days after seed sowing.

Root length, edible root length, and root diameter

Root length, edible root length, and root diameter of beetroot varieties differed significantly at 0<0.05 in the final harvest (Table 7). Maximum root length was recorded in Red Express-505 (14.37 cm), which was statistically at par with Ruby Red (13.53 cm), Maharaja (13.45 cm), and Action (12.81 cm). The minimum root length (10.45 cm) was found in Detroit Dark Red. Similarly, edible root length was found to be maximum in Maharaja (9.95 cm), which was statistically at par with Action (9.91 cm), and Red Express-505 (9.89 cm). The lowest edible root length was recorded in Ruby Queen (7.83 cm). Root diameter was found statistically significant and found maximum in Action (70.81 mm) which was statistically at par with Red Express-505 (69.34 mm), Madhur (69.19 mm), Ruby Red (66.28 mm), Ruby Queen (66.03 mm), Maharaja (63.72 mm), and minimum root diameter was recorded in Jhelum (59.68 mm).

Table 7: Performance of varieties of beetroot on root length, edible root length, and root diameter in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatment	*Root length (cm)*	*Edible root length (cm)*	*Root diameter (mm)*
Detroit Dark Red	10.45^{e}	8.64^{ab}	60.52^{b}
Jhelum	11.57^{cde}	8.262^{b}	59.68^{b}
Action	12.81^{abc}	9.91^{a}	70.81^{a}
Ruby Queen	11.99^{bcde}	7.83^{b}	66.03^{ab}
Ruby Red	13.53^{ab}	8.20^{b}	66.28^{ab}
Maharaja	13.45^{ab}	9.95^{a}	63.72^{ab}
Madhur	10.91^{de}	8.13^{b}	69.19^{a}
Red Express-505	14.37^{a}	9.89^{a}	69.34^{a}
Bikores	12.46^{bcd}	8.60^{ab}	60.52^{b}
SEM(±)	0.43	0.28	1.40
$LSD_{0.05}$	1.47***	1.24**	7.25*
Grand mean	12.39	8.82	65.12
CV%	8.14	9.65	7.62

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), *** significant at 0.1% (p<0.001), SEM (±)-Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance.

Root weight plant^{-1}, shoot weight plant^{-1}, economic yield, and biological yield

Root and shoot weight per plant, biological yield and economic yield of beetroot varieties differed significantly at 0<0.05 (Table 8). The maximum individual root weight was recorded in Action (220.58 gm), which was statistically at par with Red Express-505 (215.36 gm) and Madhur (211.43 gm). The minimum individual weight was found in Jhelum (173.26 gm). Similarly, shoot weight was found to be maximum in Madhur variety (122.68 gm), which was statistically at par with Action (121.83 gm) and Red Express-505 (113.61 gm), and minimum shoot weight was recorded in Jhelum (89.51 gm). Biological yield was statistically significant and found maximum in Action (57.06 t ha^{-1}), which was statistically at par with Madhur (55.68 t ha^{-1}) and Red Express-505 (54.82 t ha^{-1}), and the minimum biological yield was produced by Jhelum (43.79 t ha^{-1}). Similarly, economic yield was statistically significant and found maximum in Action (36.76 t ha^{-1}), which was statistically at par with Red Express-505 (35.89 t ha^{-1}) and Madhur (35.23 t ha^{-1}), and minimum economic yield was produced by the variety Jhelum (28.87 t ha^{-1}).

Table 8: Performance of varieties of beetroot on root weight plant^{-1}, shoot weight plant^{-1}, economic yield, and biological yield at inner Terai are of Sindhuli, Nepal, 2019/2020

Treatment	*Root weight (gm)*	*Shoot weight (gm)*	*Economic yield (t ha^{-1})*	*Biological yield (t ha^{-1})*
Detroit Dark Red	181.32^{c}	94.07^{c}	30.21^{c}	45.89^{c}
Jhelum	173.26^{c}	89.51^{c}	28.87^{c}	43.79^{c}
Action	220.58^{a}	121.83^{a}	36.76^{a}	57.06^{a}
Ruby Queen	187.81^{bc}	100.06^{bc}	31.30^{bc}	47.97^{c}
Ruby Red	187.50^{bc}	112.0^{ab}	31.24^{bc}	49.91^{bc}

Treatment	*Root weight (gm)*	*Shoot weight (gm)*	*Economic yield (t ha^{-1})*	*Biological yield (t ha^{-1})*
Maharaja	186.85^{bc}	101.1bc	31.13^{bc}	47.98^{c}
Madhur	211.43^{ab}	122.68^{a}	35.23^{ab}	55.68^{ab}
Red Express-505	215.36^{a}	113.61^{ab}	35.89^{a}	54.82^{ab}
Bikores	176.74^{c}	93.74^{c}	29.45^{c}	45.07^{c}
SEM(±)	5.87	4.15	0.97	1.63
$LSD_{0.05}$	25.17**	16.32**	4.19**	6.39***
Grand mean	193.43	105.4	32.23	49.8
CV,%	8.91	10.16	8.92	8.8

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. **significant at 1% (p<0.01), *** significant at 0.1% (p<0.001), SEM (±)- Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance

Root and shoot dry matter, total soluble solids, and pH

The effect of varieties on root dry matter percentage, leaf dry matter percentage and TSS was found highly significant (Table 9). Significantly greater root dry matter percentage was recorded in variety Action (10.37 %) which was statistically at par with Ruby Queen (10.15 %), Red Express-505 (10.06%), Detroit Dark Red (9.82 %), Madhur (9.75 %), Maharaja (9.15 %), and Ruby Red (9.11%). However, significantly lowest root dry matter percentage was recorded in Jhelum (8.72 %). The effect of varieties on shoot dry matter percentage was presented in table 9. Significantly higher shoot dry matter percentage was recorded in Action (9.07 %), which is statistically at par with the varieties Ruby Queen (8.97 %), Red Express-505 (8.76%), Maharaja (8.55 %), and Madhur (8.45%). Significantly, the lowest leaf dry matter percentage was found in the variety Bikores (7.40%). Significantly higher TSS was recorded in the variety Ruby Queen (10.97 ^{0}Brix), which was statistically at par with Madhur and Red Express-505 (10.95 ^{0}Brix), Maharaja (10.82 ^{0}Brix), Action (10.05 ^{0}Brix), and Detroit Dark Red (10.02 ^{0}Brix). Significantly, the lowest TSS was recorded in the variety Jhelum (9.45 ^{0}Brix). The effect of variety on the pH of the different varieties of beetroot was found to be non-significant.

Table 9: Performance of varieties of beetroot on root and shoot dry matter, total soluble solids, and pH in inner Terai area of Sindhuli, Nepal, 2019/2020

Treatments	*Root dry matter (%)*	*Shoot dry matter (%)*	*Total soluble solids (^{0}Brix)*	*pH*
Detroit Dark Red	9.82^{ab}	8.52^{ab}	10.02^{ab}	6.63
Jhelum	8.72^{b}	7.42^{c}	9.45^{b}	6.56
Action	10.37^{a}	9.07^{a}	10.82^{a}	6.62
Ruby Queen	10.15^{a}	8.97^{a}	10.97^{a}	6.61
Ruby Red	9.11^{ab}	7.76^{bc}	9.76^{b}	6.46
Maharaja	9.15^{ab}	8.55^{ab}	10.05^{ab}	6.36
Madhur	9.75^{ab}	8.45^{abc}	10.95^{a}	6.41
Red Express-505	10.06^{a}	8.76^{ab}	10.95^{a}	6.66
Bikores	8.80^{b}	7.40^{c}	9.60^{b}	6.28
SEM(±)	0.20	0.21	0.21	0.04

Treatments	*Root dry matter (%)*	*Shoot dry matter (%)*	*Total soluble solids (^{0}Brix)*	*pH*
$LSD_{0.05}$	1.11*	0.97**	0.91**	ns
Grand mean	9.55	8.32	10.28	6.51
CV,%	7.99	8.06	6.06	3.61

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), ns- Non-significant, SEM (±)- Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance

Beetroot quality (Organoleptic test)

The effect of varieties on taste, color and overall acceptability of beetroot is presented in table 10. The effect of varieties on taste was statistically significant. The random evaluators assigned significantly higher scores for variety Ruby Red (7.26), which was at par with Action (7.06), and Madhur (6.8). The lowest taste score was found in the variety Bikores (6.21). Similarly, a higher color value was assigned to the variety Ruby Red (7.21), followed by Action (7.08) and Detroit Dark Red (6.7), and a lower score was assigned to the variety Bikores (6.22). Overall, the evaluators tended to have significantly greater preference for variety Ruby Red (7.25), which was statistically at par with Action (7.1), Madhur (7), Ruby Queen (6.63), and Maharaja (6.62) and a lower preference was for variety Bikores (6.15).

Table 10: Performance of varieties of beetroot quality at inner Terai area of Sindhuli, Nepal, 2019/2020

Treatments	*Beetroot quality*		
	Taste (1-10)	*Color (1-10)*	*Acceptability (1-10)*
Detroit Dark Red	6.20^{c}	6.70^{abc}	6.55^{ab}
Jhelum	6.35^{bc}	6.37^{c}	6.20^{b}
Action	7.06^{ab}	7.08^{ab}	7.10^{a}
Ruby Queen	6.48^{bc}	6.52^{bc}	6.63^{ab}
Ruby Red	7.26^{a}	7.21^{a}	7.25^{a}
Maharaja	6.32^{bc}	6.45^{c}	6.62^{ab}
Madhur	6.80^{abc}	6.57^{bc}	7.00^{a}
Red Express-505	6.28^{c}	6.28^{c}	6.71^{ab}
Bikores	6.212^{c}	6.22^{c}	6.15^{b}
SEM(±)	0.67	0.11	0.12
$LSD_{0.05}$	0.13*	0.54**	0.63*
Grand mean	6.55	6.6	6.69
CV, %	7.02	5.63	6.51

Note: Means with the same letter within a column do not differ significantly at p = 0.05 by DMRT. *Significant at 5% (p<0.05), **significant at 1% (p<0.01), SEM (±)- Standard error of mean, LSD- Least significant difference, and CV- Coefficient of variance

Discussion

Effect of varieties on growth parameters

Significantly, higher plant height was found at 30 DAS, 40 DAS, 50 DAS, 60 DAS, 70 DAS, and at harvest in the variety Action, which was followed by Red Express-505 and Madhur, and the lowest was found in Bikores. The genetic makeup of the variety and its expression to the growing agro-climatic condition could be the possible reason for this variation. The finding of the present study is in line with the findings of Demisie and Tolessa (2018) in onion and Dongarwar *et al*. (2018) in radish. Likewise, a significantly higher number of leaves were in the variety Action than in other tested varieties. A higher number of leaves in Action might be due to the demand for developing beetroot plants for more carbohydrates, forcing the plants of this variety to produce more leaves. Significant cultivar effect on the number of leaves per plant was also noticed by Patel, Sharma and Verma (2015) in beetroot in fodder beet.

At harvest, significantly greater leaf length was found in the variety Action, which was statistically at par with Red Express, Madhur and Ruby Red. The difference in the leaf length among the varieties might be due to differences in their genetic traits. Similar results concerning differences in leaf length among varieties were found by Mekdes (2012) in onion. Breadth of the longest leaf had a significant effect among varieties, and Action had the longest breadth of the longest leaves, which was followed by Red Express-505 and Ruby Red. This might be due to the difference in genetic characteristics of the individual varieties. Similarly, variety Red Express-505 had a significantly greater canopy diameter, which was at par with Ruby Queen, Ruby Red, and Action. These differences among varieties might be due to the genetic makeup of the individual variety and its interaction with growing environments.

Effect of varieties on yield, yield attributing, and quality parameters

A cultivar performs differently under different agro-climatic conditions, and various cultivars of the same species grown even in the same environment often yield differently. Significant variation was observed between varieties in root diameter and root length. Root diameter as well as total root length, edible root length were recorded significantly higher in the varieties Red Express-505 and Action. Primarily, root diameter is a cultivar characteristic, as different cultivars have different shapes and sizes of the root. The varietal difference in the root diameter is in line with that obtained by Ijoyah, Sophie and Rakotomavo (2008) in beetroot, Patel, Sharma and Verma (2015) in beetroot, and Shalaby, Osman and Al-Lobbdy (2011) in sugarbeet. Similarly, the effect of varieties on the fresh weight of root and the fresh weight of shoot was significant and was higher in Action (220.58 g) and Madhur (122.68 g), respectively. The variation among varieties concerning fresh weight of leaf and fresh weight of root might be due to the genetic makeup and its interaction with growing environments. A similar result concerning fresh weight of root was reported by Ijoyah, Sophie and Rakotomavo (2008) in beetroot and Yasaminshirazi *et al*. (2020) in beetroot.

The economic and biological yield of beetroot found significantly higher in variety Action (36.76 t $ha^{-1}$and 57.06 t ha^{-1}) which was statistically at par with Madhur and Red

Express-505 and the lowest economic yield (28.87 t ha^{-1}) and biological yield was recorded in the variety (43.79 t ha^{-1}) Bikores. This might be due to the growth and yield attributing parameters, i.e. maximum number of leaves, longer leaves, wider leaves, greater canopy diameter, wider roots, and greater fresh weight of leaves and roots than other tested varieties. The difference in yield among varieties might be due to the interaction effect of genetic make and environment, as various varieties of the same species grown even in the same environment often yield differently (Jilani and Ghaffoor, 2003). Similar results were obtained by Sapkota *et.al.* (2021) in beetroot, Patel, Sharma and Verma (2015) in beetroot; Feller and Fink (2004) in beetroot. Likewise, leaf and root dry matter % were significantly higher in the variety action (9.37 % and 10.07%) than in other tested varieties of beetroot. Similar results, varietal differences with respect to root dry matter %, were reported by Takács-Hájos and Vargas-Rubóczk (2022) in beetroot, and Kahsay, Belew and Abay (2013) in onion.

Similarly, TSS was found significantly higher in Madhur (10.95 ^{0}Brix) variety and lowest in Jhelum (9.45 ^{0}Brix). The variation among varieties for TSS may be due to the good stomata conductance and nutrient absorption capacity, which provide higher carbon metabolism for higher glucose production that finally converts to total soluble solids. This was supported by the findings of Teshome and Bobo (2019), who obtained significant differences among cabbage varieties in TSS. The taste, color and overall acceptability were also significantly different among varieties. The variety Ruby Red had significantly higher scores for taste (7.26), color (7.21) and overall acceptability (7.25) than other varieties and the lowest score for taste (6.21), color (6.22), and overall acceptability (6.15) was recorded in Bikores. Such differences in taste, color and acceptability might be due to the varietal difference and the evaluator's preferences.

Conclusion

Based on the overall performance of the varieties, the Action variety performed better for most of the growth, yield and quality parameters in the inner Terai area of Sindhuli district of Nepal. Significantly, higher economic yield was obtained from the Action variety where whereas higher TSS was found from the Ruby Queen variety. Beetroot quality, such as taste, color and overall acceptability, was superior in the Ruby Red variety of beetroot. Thus, Action variety performed better in growth and yield, and Ruby Queen and Ruby Red varieties had superior quality beetroot production in the Sindhuli district of Nepal. Future research should be concentrate on evaluating the varieties across the several sites to verify the results of the present investigation. Additional research should be carried out to assess the varieties with various planting seasons in different agro-ecological regions of Nepal.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	Yes	Yes	Yes	Yes
Collected the data	Yes	No	No	No	No
Contributed to data analysis & interpretation	Yes	Yes	Yes	Yes	Yes
Wrote the article/paper	Yes	Yes	No	No	No
Critical revision of the article/paper	No	Yes	Yes	Yes	Yes
Editing of the article/paper	Yes	Yes	Yes	No	Yes
Project Administration	Yes	No	No	No	No
Supervision	No	Yes	Yes	Yes	Yes
Funding Acquisition	No	No	No	No	No
Overall Contribution Proportion (%)	60	20	10	5	5

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The author(s) solemnly declare(s) that this research has not involved any human subject (body or organs) for experimentation. It was not a clinical research. The contexts of human population/participation were only indirectly covered through literature review. Therefore, an Ethical Clearance (from a Committee or Authority) or ethical obligation of Helsinki Declaration does not apply in cases of this study or written work.

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